

New distribution records of the Star Fruit Flower Moth (*Diacrotricha fasciola*) (Lepidoptera: Pterophoridae) in Australia and Timor-Leste

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Abstract

Specimens collected in northern Australia since 2012 confirm an earlier record of Star Fruit Flower Moth (*Diacrotricha fasciola*) (family Pterophoridae) in northern Queensland and expand its known distribution to include the Northern Territory and Timor-Leste. This moth is specific to, and a serious pest of, two *Averrhoa* species (Oxalidaceae) in South East Asia.

Introduction

The Star Fruit Flower Moth (*Diacrotricha fasciola* Zeller, 1852) (Lepidoptera: Pterophoridae) is regarded as a serious pest of fruit of Carambola (*Averrhoa carambola*) in South East Asia, including the Indonesian archipelago (Zeller 1852; Meyrick 1907; Tan 1992; Waterhouse 1993; Robinson *et al.* 2001). Despite its pest status, there are actually few published specimen-based records. Zeller (1852) described the species from Java, Indonesia. Alipanah *et al.* (2011) reported it from Sentani, West Papua, Indonesia. Bainbrigge Fletcher (1932) and Sidhu *et al.* (2010) reported specimens from India, and Tan (1992) reported it from Malaysia. Photographic records of this species

exist from Taiwan (The Taiwan Biodiversity Information Facility 2012), and from Hong Kong (Hong Kong Moths 2009), as well as the first, and apparently only, record of this species in Australia from Kuranda, Queensland (Richardson 2012).

Diacrotricha fasciola is host-specific to two species of *Averrhoa* (Oxalidaceae), *A. carambola* and *A. bilimbi* (Bainbrige Fletcher 1920). These species are native to Indonesia and Malaysia, and are now widely cultivated throughout South East Asia (Orwa *et al.* 2009). In northern Australia, *A. bilimbi* is relatively uncommon (Gregory Chandler, pers. comm.) although it is grown in suburban gardens and its fruit are sold in local markets (Louis Elliot pers. comm.), whereas *A. carambola* is both a common garden plant and also grown commercially. Of the approximately 3350 commercially-grown *A. carambola* trees in Australia, 65.7% are grown in Queensland with the bulk in regional areas surrounding Rockhampton and Bundaberg. The remaining 34% are grown in the Darwin rural area and there is also a small commercial plantation in the Kimberley region of Western Australia. The estimated production potential of Carambola, at a yield of 45 kg/tree, is 150 tonnes valued at \$1.21M per year (Fanning & Diczbalis, 2013). There are no native species of *Averrhoa* in Australia and the most closely related plants in Australia are species from *Oxalis* and *Biphytum*, neither of which is known to host *D. fasciola*.

Bainbrige Fletcher (1932) summarised the biology of *Diacrotricha fasciola*. The eggs are usually laid on or near flower buds and the newly emerged larvae bore into the flower buds, but they do not feed on leaves. The larvae are dark pink in colour (Figure 1) but they turn green prior to pupation (Figure 2). The pupae are light green and are attached to the underside of leaves by strands of silk in an upright position. Pupation lasts only a few days. The adults (Figure 3) readily fly when leaves are disturbed, but do not move far from the host plant.

The detection of a population of *D. fasciola* near Darwin prompted more extensive surveys for this pest across northern Australia and in Timor-Leste.

Methods

Surveys for *Diacrotricha fasciola* were conducted at a range of sites in northern Australia and in Timor-Leste (Table 1). Adults were collected by sweep netting foliage of Carambola or directly by hand from leaves. Larvae were dislodged from Carambola buds and blossoms by beating into a white tray held underneath the flowers. Pupae were located by visual examination of the underside of the leaves. Larvae and pupae were reared in plastic rearing cages with a mesh lid and plenty of foliage and inflorescence. A series of larvae were immersed in near boiling water for 1 minute then preserved in 70% ethanol for permanent storage. Additionally, pterophorid moths lodged in the Northern Territory Economic Insect Collection and the Museum and Art Gallery of the Northern Territory were searched for specimens of *D. fasciola*.



Figure 1. Early instar larva *Diacrotricha fasciola* feeding on bud of *Averrhoa carambola*. (Brian Thistleton)

Figure 2. Final instar larva of *Diacrotricha fasciola* is green upon pupation. (Brian Thistleton)



Figure 3. Adult *Diacrotricha fasciola*. (Brian Thistleton)

A range of reared and collected adults were pinned and the genitalia of male and female specimens were prepared according to the method described by Robinson (1976), with some modifications. The following suite of characters served to separate adult *D. fasciola* from other Pterophoridae known from Australia and from the two congeneric species listed by Gielis (2003a) and Alipanah *et al.* (2011), and these were used to confirm the identity of specimens. The forewing lobes are deeply cleft and finely pointed. There is a distinctive pattern of markings on the abdomen and forewing, in particular dark markings on the leading edge of the hind lobe of the forewing. There are prominent upraised scales on top of the head (Diakonoff 1952) (Figure 3).

A small piece of tissue from each of the specimens listed in Table 2 was subjected to DNA extraction using the DNeasy Blood and Tissue Kit (QIAGEN, Doncaster, Australia) following the manufacturer's instructions. The DNA was eluted in 200 μ L of AE buffer and stored at -20°C . The LCO1490 and HCO2198 primers (Folmer *et al.* 1994), which target the 5' end of the cytochrome oxidase subunit 1 mitochondrial gene commonly referred to as the DNA barcode region (Hebert *et al.* 2003), were used for PCR amplification as described in Bellis *et al.* (2013).

The following acronyms refer to repositories where material has been lodged or accessed:

NTQIC	Northern Territory Quarantine Insect Collection, Darwin
NTEIC	Northern Territory Economic Insect Collection, Darwin
MAGNT	Museum and Art Gallery of the Northern Territory, NT

Table 1. Sites surveyed for *Diarmorpha javicola* and specimen collection details. The word "NIL" in the final column indicates that no specimens were detected.

Country	Region	Location	Latitude	Longitude	Date inspected	Surveillance team	Specimens collected/lodged
Australia	NT	Bees Creek	12.5936°S	131.0542°E	05 MAR 2013	SJ Anderson, G A Bellis	5 [♂] , 7 [♀] , NTQIC
Australia	NT	Bees Creek	12.5936°S	131.0542°E	17 APR 2013	B Thistleton, G A Bellis, SJ Anderson	38 NTQIC, 62 NTQIC
Australia	NT	Acacia Hills	12.7500°S	131.1500°E	01 FEB 2012	B Sandry	2 NTQIC
Australia	NT	Girraween	12.5481°S	131.0908°E	MAR 2013	W Speed	3 [♀] NTQIC
Australia	NT	Alawa	12.3808°S	130.8755°E	05 JUN 2013	SJ Anderson	2 [♂] NTQIC
Australia	NT	Lambells Lagoon	12.5061°S	131.1887°E	14 MAR 2014	SJ Anderson	1 [♂] , 1 [♀] NTQIC
Australia	NT	Wagait Beach	12.4311°S	130.7507°E	11 MAR 2014	G A Bellis	3 [♀] NTQIC
Australia	NT	Jingili	12.4402°S	130.8541°E	04 NOV 2014	SJ Anderson	1 NTQIC
Australia	NT	Stuart Park	12.4397°S	130.8794°E	04 NOV 2014	SJ Anderson	1 NTQIC
Australia	Qld	Redlynch Valley, via Cairns	16.9567°S	145.6897°E	28 APR 2013	J A Walker	1 [♂] , 8 [♀] , NTQIC
Australia	Qld	Cooktown	15.2860°S	145.1457°E	13 FEB 2014	G A Bellis	3 [♂] , 2 [♀] , NTQIC
Australia	Qld	Aderton	17.2667°S	145.2667°E	APR 2013	J A Walker	NIL
Australia	WA	Kununurra	15.7223°S	128.6923°E	10 JUN 2013, 8 SEP 2014	L Halling	NIL
Australia	WA	Broome	17.9865°S	122.2043°E	25 APR 2013	L Halling	NIL
Australia	WA	Djarrdjinn, Dampier Peninsula	16.5152°S	122.8949°E	23 APR 2013	R James	NIL
Timor-Leste	Lautem	Lolita via Lospalos	8.5256°S	127.0041°E	09 MAY 2013	G A Bellis	2 NTQIC
Timor-Leste	Lautem	Suko Loré I	8.6808°S	126.9967°E	10 MAY 2013	G A Bellis	2 [♂] NTQIC
Timor-Leste	Dili	Comoro	8.4846°S	125.5551°E	20 MAY 2013	G A Bellis	4 [♂] NTQIC

Results

Specimens of *Diacrotricha fasciola* were detected from the northern part of the Northern Territory, northern Queensland and the northern coast of Timor-Leste (Table 1). At all sites harbouring *D. fasciola*, adult moths were easily seen after being disturbed during sweep netting activities. No moths were detected at Atherton, Kununurra, Broome or the Dampier Peninsula (Table 1).

The cytochrome oxidase subunit 1 gene was amplified from four specimens with consensus sequence readings greater than 550 bp. One specimen had a consensus reading of less than 300 bp, which is too short to be considered as a DNA barcode and was not submitted to GenBank (data not shown). All consensus sequences had over 99% sequence similarity with specimens from the family Pterophoridae from private entries to GenBank which are yet to be released to the public. There were no high sequence similarity matches on GenBank. The DNA barcodes were submitted to GenBank and the accession numbers are listed in Table 2.

Table 2. Specimens used for DNA barcoding analysis.

Specimen identifier	Details	GenBank Accession Number
SJA00342	Australia, Bees Creek, 110 Horne Road 12.5936°S, 131.0542°E 05 MAR 2013 Sweep netting <i>Averrhoa carambola</i> Coll: S. Anderson & G. Bellis Det: E.D. Edwards Conf: D. Hobern	KM363762
ENQ33232	Australia, Acacia Hills, Mocatto Rd 12.7500°S, 131.1500°E 2012 Coll: B. Sandry	KM363763
ENQ61525	Australia, Bees Creek, 110 Horne Road 12.5667°S, 131.0500°E 17 APR 2013 Coll: B.M. Thistleton, S.J. Anderson & G.A. Bellis Det: E.D. Edwards	KM363765

Discussion

It is unlikely that *Diacrotricha fasciola* is native to Australia as neither of its host plants is native to this country. The widespread distribution and lack of previous reports of *D. fasciola* throughout the Darwin rural area suggests this species has been able to establish undetected and disperse between Carambola crops since 2012. This relatively widespread occurrence is most likely nowadays a reflection of the low priority given to the pest fauna of this plant due to its low economic importance in this region rather than indicating a recent detection.

Adult *Diacrotricha fasciola* are readily visible following disturbance by sweep netting. This high visibility, plus Tan's (1992) discovery of *D. fasciola* on every farm growing Carambola that was inspected in Malaysia, lends credence to the negative results reported here from Western Australia. Even so, no specimens were observed on the single tree inspected at Atherton in Queensland, so it would be prudent to resurvey Carambola crops in areas free from *D. fasciola* whilst plants are flowering to maximise the chances of detecting this pest. Areas apparently free from infestation of *D. fasciola*, such as northern Western Australia, would benefit from maintaining this pest-free status.

There is little known about the dispersal and ecology of *D. fasciola*. Wind-assisted dispersal has been suggested as the agent responsible for the sudden appearance of other species of Lepidoptera in northern Australia, which presumably arrived from Timor-Leste (Braby *et al.* 2014) or from New Guinea (Royer 2009), and this may also be the pathway used by *D. fasciola* to enter northern Australia. The lack of reports of this species from Papua New Guinea (Gielis 2003b), however, casts doubt over that country as the origin of the Queensland populations. Surveys of Carambola plantings from the northern Cape York Peninsula and from New Guinea may clarify the status of *D. fasciola* in this region. Alternatively, DNA analyses could potentially be used to compare the genetic diversity of Northern Territory and Queensland populations which may help to elucidate the source of these populations.

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References

- Agroforestry Database (2009) *Tree reference and selection guide version 4.0*. <http://www.worldagroforestry.org/treedb2/AFTPDFS/Averrhoa_bilimbi.pdf> (accessed 19 November 2014).

- Alipanah H. *et al.* (2011) Phylogenetic relationships in the tribe Oxyptilini (Lepidoptera, Pterophoridae, Pterophorinae) based on morphological data of adults. *Zoological Journal of the Linnean Society* 163, 484–547.
- Arenberger E. (1986a) Die Agdistis-Arten der äthiopischen Region (1. Beitrag) (Lepidoptera, Pterophoridae). *Mitteilungen der Schweizerischen Entomologischen Gesellschaft* 59, 187–196.
- Arenberger E. (2002) *Microlepidoptera Palaearctica*, vol. 9: Pterophoridae 2. Goecke & Evers, Keltern.
- Bainbrigge Fletcher T. (1920) *Memoirs of the Department of Agriculture in India. Life-Histories of Indian Insects Microlepidoptera vol. 6, no.1.* Agricultural Research Institute, Thacker, Spink & Co., Calcutta.
- Bainbrigge Fletcher T. (1932) *Life-Histories of Indian Microlepidoptera (Second Series) Alucitidae (Pterophoridae), Tortricina and Gelechiadae. Scientific Monograph No. 2.* The Imperial Council of Agricultural Research, Calcutta.
- Bellis G.A. *et al.* (2013) New records of Delphacini (Hemiptera: Delphacidae: Delphacinae) from Australia, Timor-Leste and Papua New Guinea, and an updated checklist of Delphacini from Australia. *Austral Entomology* 53, 167–174.
- Braby M.F., Bertelsmeier C., Sanderson C. and Thistleton B.M. (2014) Spatial distribution and range expansion of the Tawny Coster butterfly, *Acraea terpsicore* (Linnaeus, 1758) (Lepidoptera: Nymphalidae), in South-East Asia and Australia. *Insect Conservation and Diversity*, 7, 132–143.
- Diakonoff A. (1952) Microlepidoptera of New Guinea. Results of the 3rd Archbold Expedition (Pterophoridae). *Verhandelingen der Koninklijke Nederlandse Akademie van Wetenschappen, Verb. Afd. Natuurkunde* (2) 44, 1–167.
- Fanning K. and Diczbalis Y. (2013) *Collation of health literature for tropical fruits and extracts.* Rural Industries Research and Development Corporation, Canberra.
- Folmer O. *et al.* (1994) DNA primers for amplification of mitochondrial cytochrome c oxidase subunit 1 from diverse metazoan invertebrates. *Molecular Marine Biology and Biotechnology* 3, 294–299.
- Gielis C. (2003a) *World Catalogue of Insects, vol. 4: Pterophoroidea and Alucitoidea (Lepidoptera).* Apollo Books, Stenstrup.
- Gielis C. (2003b) Review of the Pterophoridae from New Guinea, with descriptions of eight new species (Lepidoptera). *Zoologische Mededelingen, Leiden* 77, 349–391.
- Hebert P.D.N., Cywinska A., Ball S.L. and deWaard J.R. (2003) Biological identifications through DNA barcodes. *Proceedings of the Royal Society of London, Series B* 270, 313–321.
- Hong Kong Moths (2009) *Star fruit flower moth.* <<http://www.inaturalist.org/taxa/211098-Diacrotricha-fasciola>> (accessed 19 November 2014).
- Lim T.K. (1996) *Carambola Characteristics and Cultivars. Agnote No. D27.* Northern Territory Department of Primary Industries, Darwin.
- Meyrick E. (1907) Notes and descriptions of Pterophoridae and Orneodidae. *Transactions of the Entomological Society of London* 55, 471–511.
- Nielsen E.S., Edwards E.D. and Rangsi T.V. (ed.) (1996) *Monographs on Australian Lepidoptera. Checklist of the Lepidoptera of Australia.* CSIRO, Canberra.
- The Papua Insects Foundation (2014) *The Plume Moths (Lepidoptera: Pterophoridae) of Papua Indonesia.* <<http://www.papua-insects.nl/insect%20orders/Lepidoptera/Pterophoridae/Pterophoridae%20list.htm>> (accessed 19 November 2014).
- Richardson B. (2012) *Leap Frog Oz* <<http://www.leapfrogoz.com.au/LeapFrogOz/Home.html>> (accessed 19 November 2014).

- Robinson G.S. (1976) The preparation of slides of Lepidoptera genitalia with special reference to Microlepidoptera. *Entomologist's Gazette* 27(2), 127–132.
- Robinson G.S. *et al.* (2001) *Host plants of the moth and butterfly caterpillars of the Oriental Region*. Department of Entomology, The Natural History Museum, London, and Southdene SDN BHD, Malaysia.
- Royer, J. (2009) Spread of red-banded mango caterpillar, *Deanolis sublimbalis* Snellen (Lepidoptera: Pyralidae), in Cape York Peninsula, Australia. *Australian Entomologist* 36, 119–130.
- Short P.S. *et al.* (2011) *Checklist of the Vascular Plants of the Northern Territory*. Northern Territory Herbarium, Department of Natural Resources, Environment, The Arts and Sport, Darwin.
- Sidhu A.K., Chandra K. and Pathania P.C. (2010) *A check-list of microlepidoptera of India (Part-1: Family Pterophoridae)*. Zoological Survey of India, Calcutta.
- Taiwan Biodiversity Information Facility (TaiBIF) (2012) *The National Checklist of Taiwan*. <<http://www.gbif.org/species/116117581>> (accessed 19 November 2014).
- Tan C.L. (1992) Lepidopteran pests of star fruit (*Averrhoa carambola*) and their parasitoids in Peninsular Malaysia. *Journal of Plant Protection in the Tropics* 9, 43–49.
- Tutt J.W. (1905) Types of the genera of the argdistid, alucitid and orncodid plume moths. *Entomologist's Record and Journal of Variation* 17, 34–37.
- Waterhouse D.F. (1993) *The Major Arthropod Pests and Weeds of Agriculture in Southeast Asia*. ACLAR Monograph No. 21. Australian Centre for International Agricultural Research, Canberra.
- Zabedah Mahmood T.A., Malik T.M., Indu Bala J. and Rahman A.M. (2013) *Malaysian Carambola: From a rising star to a global leader*. The Malaysian Agricultural Research and Development Institute, Malaysia.